RECEIVED
JUN 29 1943
O. S. U. LIBRARY

C. 7242

May 1943

UNITED STATES
DEPARTMENT OF THE INTERIOR
HAROLD L. ICKES, SECRETARY

BUREAU OF MINES
R. R. SAYERS, DIRECTOR

INFORMATION CIRCULAR

SYNTHETIC RUBBER

ITS PRODUCTION FROM PETROLEUM, COAL, AND OTHER MATERIALS

BY

W. C. HOLLIMAN

I.C. 7242,
May 1943.

INFORMATION CIRCULAR

UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

SYNTHETIC RUBBER

Its Production from Petroleum, Coal, and Other Materials[1]

By W. C. Holliman[2]

CONTENTS

	Page
Introduction	2
Acknowledgments	3
Literature on synthetic rubber	3
Chemical classification of synthetic rubbers	4
Plastic substances with certain rubberlike properties	5
Physical properties	6
Raw materials for production of crude synthetic rubber	6
Butadiene	6
Styrene	7
Acrylonitrile	7
Chloroprene	8
Isoprene	8
Dimethylbutadiene	8
Isobutylene	8
Alkali polysulfides and organic dihalides	8
Vinyl chloride	8
Description of properties of the individual synthetic rubbers	9
Buna 85	9
Buna 115	10
Buna S	11
Buna SS (formerly Levulkan)	12
Perbunan (formerly Buna N)	12
Perbunan extra	14

---

[1] The Bureau of Mines will welcome reprinting of this paper provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Inf. Circ. 7242."

[2] Assistant research chemist, Petroleum Experiment Station, Bartlesville, Okla.

CONTENTS (Cont'd.)

Page

Description of properties of the individual synthetic rubbers (Cont'd.)
SKA and SKB (Russian Sodium Divinyl Rubber) 14
Ker 15
Hycar O R (Ameripol) 15
Chemigum 17
Neoprene 18
Sovprene 19
Mustone 19
Methyl rubber 20
Vistanex 21
Oppanol 22
Butyl rubber 22
Flexon 23
Thiokol 24
Thiokol R D 26
Ethanite 27
Perduren 27
Thionite and Thionoc 28
Vulcaplas 28
Koroseal and Korogel 29
Flamenol 30
Agripol 31
Bibliography 32

INTRODUCTION

Commercial production of synthetic rubber in the United States became a reality in 1931 when E. I. duPont de Nemours, Inc., announced the manufacture of Duprene, a synthetic rubber made by polymerizing chloroprene. Duprene was later improved and reintroduced as neoprene. Since 1931 other synthetic rubbers and rubberlike materials have been announced and are now produced commercially or are in the pilot-plant stage in the United States. These include Thiokol, Buna S, Perbunan, Koroseal, Vistanex, Flamenol, Ameripol or Hycar, Chemigum, Butyl rubber, and Flexon. None of these is synthetic rubber in the strict chemical meaning of the word synthetic, as none is identical in chemical structure with natural rubber. However, all possess some of the physical properties of natural rubber, and in addition usually have some outstanding property not found in natural rubber that makes them superior for certain uses. Because of these superior qualitites, a considerable demand had arisen for synthetic rubbers before the present emergency, although the price was several times that of natural rubber.

Synthetic-rubber production in other countries began about 1934. The rubbers that have been announced include the Buna rubbers, Oppanol, and Perduran in Germany, SKA, SKB, and Sovprene in Russia, Ker in Poland, Ethanite in Belgium, Mustone and Thionite in Japan, and Vulcaplas in England. Methyl rubber, now of historic interest only, was produced in Germany during the first World War. In some of these countries, particularly Germany and Russia, the manufacture of synthetic rubber was not prompted by its superior qualities, but was part of their program of economic selfsufficiency.

The influence of the present war on the rubber situation in the United States is too well known to be recounted. It is sufficient to say that demand for synthetic rubber in the United States no longer depends on its superiority for particular uses but is based upon economic and military necessity. For this reason the synthetic-rubber production program has been enlarged from actual production of 17,000 long tons in 1941 (all types) to a planned annual production of approximately 900,000 tons. Further, the new program has been frozen to include only those types that will best satisfy immediate war and economic needs. These, according to the recommendations of the Baruch committee, are Neoprene (60,000 tons), Butyl rubber (132,000 tons), Buna S (845,000 tons), and Thiokol (60,000 tons).

The purpose of this paper is to catalogue for quick reference general information taken from technical journals regarding the chemistry and physical properties of the synthetic rubbers produced commercially in the United States and other countries.

ACKNOWLEDGMENTS

This paper was prepared under the general supervision of R. A. Cattell, chief, Petroleum and Natural Gas Division, Bureau of Mines, Washington, D. C., and under the immediate direction of N. A. C. Smith, supervising engineer, Petroleum Experiment Station, Bartlesville, Okla. The writer is indebted to Mr. Smith and to A. J. Kraemer, R. V. Smith, C. C. Ward, and other members of the Bureau of Mines staff for their helpful suggestions and assistance in preparing the report. Especial thanks are extended to the Research Division of the Phillips Petroleum Co. for its courtesy in permitting use of its technical library; to Gustav Egloff and the Universal Oil Products Co., who supplied the translations of articles from the Russian literature; and to M. R. Mandelbaum, of the Refining Division, Petroleum Administration for War, who reviewed the manuscript.

LITERATURE ON SYNTHETIC RUBBER

The literature on synthetic rubber is voluminous, comprising a thousand or more articles, most of them in American, English, German, or Russian journals. Russian journals alone contained more than 300 articles dealing particularly with the sodium divinyl rubber manufactured in the U. S. S. R. The volume of American literature on synthetic rubber has increased tremendously within the past few years, particularly since synthetic rubber has become nationally important. Within the last few months several journals have devoted issues exclusively to the subject, among them Industrial and Engineering Chemistry for November 1942, Oil and Gas Journal for November 26, 1942, and Petroleum Refiner, October 1942. Much of the literature consists of reviews, semitechnical or popular articles, general descriptions of a single variety of synthetic rubber or of some specific property of this variety, or vague and incomplete discussions and repetitive articles lacking factual data. Several of the reviews are considered outstanding, as are some of the articles dealing with a single variety. Many of the articles have been sponsored by manufacturers of particular varieties and presumably contain the most authoritative information concerning them.

Detailed descriptions of actual polymerization operations are not numerous. An exchange of data regarding these methods between interested manufacturers has been effected under the rubber-production program, but not much has been published as yet. A considerable amount of patent literature is available, abstracts of which have been summarized by Voge,[3] Marchionna,[3] and others.

A short list of selected articles by leaders in this and allied fields is appended to this paper. These and others not listed were of considerable value to the writer in assembling data for this report. There are many other worthwhile articles, of course, and the reader's attention is directed particularly to the special issues mentioned hereinbefore.

CHEMICAL CLASSIFICATION OF SYNTHETIC RUBBERS

Early attempts to synthesize rubber were directed toward development of a product that would chemically and physically duplicate natural rubber and could thus be truly designated by the term "synthetic". This approach to the problem was abandoned, however, and further research was directed toward production of substances of any chemical nature that could replace natural rubber. In those countries where economic selfsufficiency has prompted such research, the effort has been to find substances to replace natural rubber at the lowest possible cost. In the United States this search has been directed toward production of materials definitely superior in some manner to natural rubber. The interchange of ideas before the present war, through patents and otherwise, resulted in the manufacture of similar synthetic rubbers in the various countries. Thus Vistanex, made in the United States, is similar to Oppanol, which was first made by I. G. Farbenindustrie in Germany; and the Buna-type rubbers made in the United States also were developed in Germany and manufactured here through patent-right exchanges.

---

[3] See bibliography at end of paper.

Chemically, the synthetic rubbers may be divided into several types. Several schemes are used, and various nomenclatures have been suggested. The types announced to date include the following:

Butadiene polymers and copolymers
(all the Buna-type rubbers, Ameripol or Hycar, Chemigum, SKA and SKB or the Russian Divinyl rubbers, and Ker).

Substituted butadiene polymers
(chloroprene polymers: Neoprene, Mustone, and Sovprene; dimethyl-butadiene polymers; methyl rubber; isoprene polymers: includes natural rubber).

Butene polymers and copolymers
(Vistanex, Oppanol, butyl rubber, and Flexon).

Organic polysulfides
(Thiokol, Thionite, Vulcaplas, and Perduren).

Plasticized vinyl chloride polymers
(Koroseal and Flamenol).

Plastic Substances With Certain Rubberlike Properties

Another system of classification proposed by Fisher suggests a new nomenclature in which synthetic rubbers and rubberlike materials are called "elastomers," and the term "plastomer" is used for the true thermoplastics and thermosetting plastics. Elastomers are further divided into elastoprenes, elastolenes, elastothiomers, and elastoplastics. The elastoprenes include the butadiene and piperylene rubbers (no piperylene rubbers are manufactured commercially) and the substituted butadiene rubbers, including isoprene, dimethylbutadiene, and haloprene. The elastolenes include the polymers of the isobutenes, and the elastothiomers are the organic polysulfides, whereas the term "elastoplastics" is applied to the plastics with rubberlike properties, including plasticized vinyl chloride polymers. This nomenclature has not been generally accepted, as the term "synthetic rubber" to describe all artificial rubberlike materials has already attained wide use.

Physical Properties

Rubber possesses a peculiar combination of physical properties. It is unusual in its elasticity, flexibility, tensile strength, abrasion resistance, impermeability to liquids and gases, hysteresis, heat resistance, chemical resistance, aging resistance, dielectric strength, degree of hardness, plasticity and adaptability to vulcanization and processing. Improvements in methods of compounding have enabled rubber technologists to develop to a maximum the properties desired for particular purposes. Comparison of natural rubber and the various synthetic rubbers with respect to these properties shows that each may possess certain qualities favorable for certain purposes. For example, elasticity of a synthetic rubber may not equal that of natural rubber, but the resistance to chemicals and aging qualities may be so much more favorable for a particular use that elasticity may be sacrificed to a certain degree.

RAW MATERIALS FOR PRODUCTION OF CRUDE SYNTHETIC RUBBER

Crude synthetic rubber is produced in two steps - first, the raw material for polymerization, and second, the actual polymerization operation. The principal raw materials for polymerization, in the case of butadiene polymers and copolymers, consist of butadiene, styrene, and acrylonitrile. The unpolymerized unit of Neoprene and Sovprene is chloroprene or 2-chloro-1, 3-butadiene; of methyl rubber is dimethylbutadiene; and of natural rubber the unpolymerized unit is isoprene. The butene polymers, Vistanex and Oppanol, require isobutylene for manufacture, whereas the copolymers, Butyl rubber and Flexon, require isobutylene, together with a diolefin such as butadiene or isoprene. The organic polysulfides are reaction products between an alkali polysulfide and an organic dihalide, whereas the plasticized vinyl chloride polymers require vinyl chloride and a plasticizing agent such as tricresyl phosphate.

Butadiene ($H_2C=CH-CH=CH_2$)

Butadiene is the most important of the raw materials for synthetic rubber under the present production program. It may be made by many methods from a number of basic materials. A series of articles by Egloff and Hulla, presenting a complete summary of known butadiene sources, appeared in the Oil and Gas Journal of November 5, 1942 and subsequent issues. The present commercial sources of butadiene are petroleum and petroleum gases, coal or coke and limestone, ethyl alcohol, and butylene glycol made by special fermentation of grain.

Butadiene from petroleum or petroleum products or gases may be obtained in several ways, among which are the following:

1. Thermal cracking of petroleum fractions at a high temperature.

2. Direct catalytic dehydrogenation of normal butane or of butanes and butenes produced by cracking.

3. From acetylene formed by pyrolysis of natural gas.

4. From alcohol manufactured from ethylene obtained as a byproduct in cracking petroleum or by dehydrogenation of ethane.

In Germany, butadiene is made from coke and limestone in the following steps: Coke and lime ——› calcium carbide ——› acetylene ——› acetaldehyde ——› aldol ——› butylene glycol——› butadiene. Butadiene may also be made from acetylene by conversion to vinylacetylene and hydrogenation to butadiene.

Butadiene production from grain or vegetable products involves preliminary fermentation to obtain alcohol, which is converted to butadiene in one of several ways involving dehydration and dehydrogenation. In Russia, this is accomplished in one step by use of a special catalyst, whereas the process used in the United States has two steps and that used by the Germans has four steps.

Butadiene can also be made from grain by a special fermentation process that produces butylene glycol, which is dehydrated to give butadiene.

Styrene ($C_6H_5CH=CH_2$)

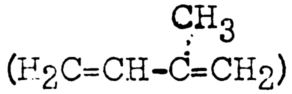
Styrene has been manufactured for some time for use in the plastics industry; hence, the principles involved in its production are well known. The most common method consists of catalytically dehydrogenating ethyl benzene produced from benzene and ethylene or ethyl alcohol. Styrene may also be produced by high-temperature cracking of petroleum, but subsequent separation is difficult.

Acrylonitrile ($H_2C=CHC\equiv N$)

Acrylonitrile is made by treating ethylene with hypochlorous acid to give ethylene chlorohydrin, which reacts with sodium cyanide to give hydracrylic nitrile, from which acrylonitrile is obtained by dehydration.

Chloroprene ($H_2C=CH-CCl=CH_2$)

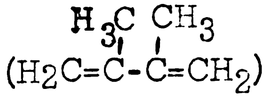
Calcium carbide, made from lime and coke in a high-temperature electric furnace, gives acetylene when treated with water. Vinylacetylene, formed by polymerization of two molecules of acetylene, is treated with hydrochloric acid to give chloroprene.



Isoprene ($H_2C=CH-\overset{CH_3}{C}=CH_2$)

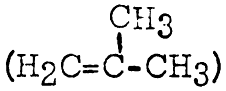
Except for possible use in Butyl rubber as the diolefin to furnish the required unsaturation, production of isoprene has at present no significance in the synthetic-rubber industry.

Isoprene is a product of destructive distillation of natural rubber, and is also formed synthetically in small amounts in petroleum cracking. Processes have been developed that use coal tar, starch, turpentine, calcium carbide, or petroleum products as starting materials.



Dimethylbutadiene ($H_2C=\overset{H_3C}{C}-\overset{CH_3}{C}=CH_2$)

Dimethylbutadiene is the basic material for methyl rubber and is now of historic interest only. It was made by the Germans during World War I from acetone obtained from calcium carbide.



Isobutylene ($H_2C=\overset{CH_3}{C}-CH_3$)

Isobutylene is the principal ingredient in the manufacture of Butyl rubber and also is an important material in the manufacture of high-octane gasoline. This hydrocarbon is present in large quantities in gases from refinery cracking operations, and it may be made by dehydrogenation of isobutane, which is obtained from natural gases or from isomerization of normal butane.

Alkali Polysulfides and Organic Dihalides

The alkali polysulfides used in Thiokol and the like are made from sulfur and alkali. The organic dihalides are made by halogenation of organic products usually obtained from petroleum. For example, ethylene dichloride is made by chlorination of the olefin from cracked gas with chlorine obtained from salt.

Vinyl chloride ($H_2C=CHCl$)

Vinyl chloride is produced commercially by any of three methods - (1) catalytic combination of acetylene and hydrogen chloride (2) chlorination of ethylene to ethylene dichloride and partial dehydrohalogenation by treatment with alcoholic caustic, or (3) by vapor-cracking ethylene dichloride.

DESCRIPTION OF PROPERTIES OF THE INDIVIDUAL SYNTHETIC RUBBERS

The synthetic rubbers manufactured in the United States and other countries are listed below under their trade names, together with abstracts of general information regarding their structure, manufacture, and physical properties the writer was able to gather from the literature. There are, of course, other possible synthetic rubbers not yet made commercially, such as piperylene rubber, which has been made in the laboratory. Rubber-like materials also have been made from such primary materials as soybean oil or lactic acid, but little information is available regarding their chemistry or manufacture. Commercial production of one such material, Agripol, has been announced recently, and its description is included in the abstracts below.

Systematic research doubtless will reveal many other materials that may be superior to and involve less complicated manufacturing procedure than those synthetic rubbers now known.

Buna 85

Type: Polymerized butadiene.

Structure: $[-CH_2-CH=CH-CH_2-]_x$.

Manufacturer: I. G. Farbenindustrie, Germany.

Date announced (first available reference): 1935.

Present status of manufacture: In 1940, Buna 85 was listed as being made only on a small scale for use in making hard rubber.

Method of synthesis: Polymerization of butadiene in the presence of sodium metal.

Raw materials: Butadiene.

Source of raw materials: Coke and lime. (See Butadiene.)

Method of vulcanizing: Same as natural rubber.

Method of processing: Soft, plastic, and easily workable on regular rubber machinery.

Summary of properties:

Relatively low molecular weight.

Lower than natural rubber in tensile strength and elasticity.

Behaves like natural rubber in organic swelling agents.

Abrasion resistance about the same as natural rubber.

Electrical properties superior to natural rubber.

Aging properties better than natural rubber.

Heat resistance equal or superior to natural rubber.

Especially adapted to manufacture of hard rubber because of high thermal softening point and extraordinary chemical resistance of its hard-rubber vulcanizates, which, however, are more brittle than hard, natural rubber.

Buna 115

Type: Polymerized butadiene.

Structure: Same as Buna 85, except for higher molecular weight or degree of polymerization.

Manufacturer: I. G. Farbenindustrie, Germany.

Date announced (first available reference): 1935.

Present status of manufacture: In the 1940 article by Koch (see bibliography) relating to synthetic rubbers made by I. G. Farbenindustrie, Buna 115 is not listed.

Raw materials and source: Same as Buna 85.

Method of vulcanizing and compounding: Same as natural rubber; plastic and easily processed.

Discussion of properties: Properties of Buna 115 are generally similar to those of Buna 85, except that the difference in molecular weight alters them somewhat, as, for example, abrasion resistance is listed as slightly better than in natural rubber or Buna 85, although poorer than in Buna S or Buna N.

Buna S

Type: Copolymerized butadiene and styrene.

Structure: $[(-CH_2-CH{=}CH-CH_2)_x-CH_2-\overset{|}{C}HC_6H_5]_y$.

Manufacturer: I. G. Farbenindustrie, Germany. Standard Oil Co. of New Jersey, and other companies operating under Standard Oil Co. patent licenses and under the direction of the War Production Board.

Date announced (first available reference): 1935.

Method of synthesis: Copolymerization in aqueous emulsion.

Present status of manufacture: Buna S has been made in large quantities in Germany since 1936 as a general substitute for rubber, particularly in automobile tires. Standard Oil Co. and Firestone Tire & Rubber Co. already have been manufacturing it in the United States, although only 4,000 long tons of Buna types were made here in 1941. Under present plans it is now to be manufactured by a number of companies on a large scale for use in tires and as a general substitute for natural rubber. Under the present program an annual production of 705,000 tons is planned, and the Baruch Committee has recommended that this be increased to 845,000 tons.

Raw Materials: Butadiene and styrene.

Source of raw materials: See Butadiene and styrene.

Method of vulcanizing: Same as natural rubber.

Method of processing: Plasticized by carefully controlled hot-air treatment.

Discussion of properties and uses: In literature inspired by I. G. Farbenindustrie, it is stated that Buna S is by no means to be considered a mere substitute for natural rubber as it constitutes such an improvement in heat resistance and abrasion resistance, and it is claimed that automobile tires made of it show 35 percent better wear than natural-rubber tires.

In general, the properties of Buna S are very similar to those of natural rubber, and the swelling characteristics in gasoline and mineral oil are but little better than those of natural rubber. Water absorption is only 65 percent that of natural rubber, and aging qualities are considered superior. It is useful for coverings in the cable industry because of the last-named qualities.

Buna S is now made in larger quantities than any other synthetic rubber for use in automobile tires and general replacement for natural rubber.

Buna SS (formerly Levulkan)

Type: Copolymerized butadiene and styrene.

Structure: Same as Buna S, except that the proportion of styrene is greater.

Manufacturer: I. G. Farbenindustrie, Germany.

Date of first available reference: 1935.

Present status of manufacture: Buna SS is not mentioned in the April 1940 article by Koch but is mentioned in article of September 1940 by Gartner (see bibliography).

Method of synthesis: Same as Buna S.

Raw materials and source: Same as Buna S.

Method of processing and vulcanizing: Same as Buna S.

Discussion of properties: Buna SS differs from Buna S in the proportion of styrene used. Some data showing the effect of this difference on the properties applied particularly to the manufacture of hard rubber linings are given in the article by Gartner mentioned above. Buna SS is said to possess qualities that make it especially favorable as an insulation for cable.

Perbunan (formerly Buna N)

Type: Copolymerized butadiene and acrylonitrile.

Structure: $[-(CH_2-CH=CH-CH_2)_x-CH_2-CHC\equiv N-]_y$.

Manufacturers: I. G. Farbenindustrie, Germany; Standard Oil Co. of New Jersey, Firestone Tire & Rubber Co., and other companies licensed by Standard.

Date announced: About 1935.

Date of first available reference: 1936.

Present status of manufacture: First made in Germany. Patent rights in America held by Standard Oil Co. of New Jersey. Present production figures not available.

Method of synthesis: Copolymerization of butadiene and acrylonitrile in aqueous emulsion.

Raw materials: Butadiene and acrylonitrile.

Source of raw materials: See Butadiene and Acrylonitrile.

Method of vulcanizing: Like natural rubber.

Method of processing: Perbunan cannot be plasticized like Buna S with hot air and does not break down completely on long mastication. Softeners are necessary to increase elasticity, tack, and assist in extruding. Addition of natural rubber, up to 20 percent, improves working qualities without noticeably changing swelling characteristics. Perbunan is much tougher and more difficult to process than natural rubber. It generates more heat in milling, is less thermoplastic, but has a tendency to harden at higher temperatures, and its plasticity is less pronounced during mastication than is natural rubber.

Discussion of physical properties: A primary property of Perbunan is its resistance to gasoline, petroleum, and aliphatic hydrocarbons. However, it is soluble in aromatic and chlorinated hydrocarbons such as benzol, toluol, solvent naphtha, di- and tri-chlorethylene, and in certain ketones.

Aging qualities and resistance to ozone are said to be superior to those of natural rubber, but elasticity, rebound, and electrical properties are poorer. Because of its poor electrical properties, Perbunan is not used as electrical insulation. In heat resistance and abrasion resistance it surpasses natural rubber and is less than half as permeable to air and gases. Hard compounds made from Perbunan have high softening points and superior solvent resistance. The specific gravity of Perbunan is 0.96, and the nitrogen content is about 7 percent. Like natural rubber, Perbunan will burn, but it can be made non-inflammable by adding suitable chlorine-containing materials.

Perbunan finds greatest use where its oil-resistant qualities are needed - oil-resistant packing rings, gaskets, printing rolls, gasoline hose, hose for spraying paint, cable covers, conveyor belts, and the like. Although Perbunan tread compounds are said to be equal or superior to the best rubber tread compounds, its use in tires is not of commercial importance, as other synthetics easier to process and fabricate are considered economically more suitable for that purpose.

Perbunan Extra

Type: Copolymerized butadiene and acrylonitrile.

Structure: Same as Perbunan, except that the acrylonitrile content is greater.

Manufacturers: I. G. Farbenindustrie, Germany; Standard Oil Co. of New Jersey, Firestone Tire and Rubber Co., and other companies licensed by Standard.

Date announced (first available reference): 1939.

Present status of manufacture: Patent rights in America held by Standard Oil Co. Present production figures not available.

Method of synthesis: Copolymerization of butadiene and acrylonitrile in aqueous emulsion.

Raw materials and source: Same as Perbunan.

Method of vulcanizing: Like natural rubber.

Method of processing: Perbunan and Perbunan Extra are both more difficult to mill, as described under Perbunan. However, Perbunan Extra is said to break down more readily and mill more easily than Perbunan.

Discussion of properties: Perbunan Extra is more resistant to oil than Perbunan because of the extra acrylonitrile. However, the general properties are like those of Perbunan, except that the vulcanizates are less elastic, and higher tensile values are obtained without carbon black. The specific gravity is 0.97, and the nitrogen content is 9 to 10 percent.

SKA and SKB (Russian Sodium Divinyl Rubber)

Type: Butadiene polymer.

Structure: $[-CH_2-CH=CH-CH_2-]_x$.

Manufacturer: Made in U. S. S. R.

Date announced: Manufacture of SK synthetic rubber using butadiene made from alcohol was begun in 1931.

Method of synthesis: Previous to 1935, polymerization of liquid butadiene was effected under pressure at 50° C. in enclosed vessels containing sodium-covered steel rods. A rodless method was introduced in 1935 in which the polymerization takes place in a gaseous instead of a liquid state.

Raw materials and source: Butadiene for the synthetic rubber SKA is obtained from petroleum, and for SKB from alcohol made from potatoes and other agricultural products. Because of Russian economic conditions, the principal production is from alcohol.

Present status of production: Production of more than 20,000 tons of SK synthetic rubber in 1935 was claimed, and a planned annual production of 90,000 tons by the end of 1937 was said to have been exceeded. An expanded program was included in the "third five-year plan," 1938 through 1942, but because of the war the results of this program have not been disclosed.

Discussion: The Russian sodium divinyl, or SK, synthetic rubber is similar in chemical structure to the German numbered Buna rubbers. The designations "A" and "B" refer to the source of the butadiene used for polymerization rather than to differences in the rubber produced.

SK rubber is made in several grades by varying the conditions of polymerization. Some grades are easier processed than natural rubber. Mechanical properties of pure-gum stocks are developed, as with other synthetic rubbers, by compounding with fillers and vulcanization and compare favorably with Perbunan and Buna S. SK is not oil- or solvent-resistant but resists oxidation to a great extent. It is said to be lacking in building tack, although several successful methods of overcoming this have been developed. It finds considerable use in rubber footwear as well as in tires. When used in tires, it is said to give wear in actual road service only 15 percent less than similarly compounded tires of natural rubber.

Ker

Discussion: Ker is listed by Wood (see bibliography) as a butadiene polymer made by Stomil Co. in Poland.

Hycar O R (Ameripol)

Type: Butadiene copolymer.

Structure: Not announced. Said to be a copolymer of butadiene and acrylonitrile similar to Perbunan. Two distinct types made. See below

Manufacturer: Hydrocarbon Chemical & Research Co. (Hycar Chemical Co.), a firm owned jointly by Phillips Petroleum Co. and B. F. Goodrich Co.

Date announced: 1940.

Present status of manufacture: Pilot plant completed in 1939 with capacity of 100 pounds per day. A plant having a capacity of 2,000 long tons a year was constructed in 1940. Present production figures not available.

Raw materials and source: Butadiene is made from petroleum. See Butadiene. Source or nature of copolymer not announced.

Method of polymerization: Polymerized under pressure in emulsion with soap and water.

Method of vulcanization: Like natural rubber, except less sulfur and more accelerator required.

Method of processing and compounding: Hycar is tough and does not break down on a mill to the extent natural rubber does, and more softener is required. Pigments have the same relative effect as with rubber.

Discussion of properties: Two distinct types of butadiene copolymer synthetic rubber are said to be made by the Hycar Chemical Co., both of which are marketed under the trade name Ameripol. One is a rubber suitable for tire manufacture, and the other is a special oil-resistant rubber.

Properties of Ameripol, such as tensile strength and elasticity, are said to vary over a wide range according to the method of compounding. Maximum tensile strength is obtained with channel black loading. A tensile strength up to 4,000 pounds and 600 percent elongation may be obtained. Good heat and abrasion resistance are claimed, and superior resistance to mineral, animal, and vegetable oils and fats, to oxidizing effects of metallic soaps used as driers in paints and inks, to all petroleum products, and to benzene, alcohol, water, and carbon tetrachloride, although it is badly swollen by acetone. Its age resistance is superior to that of natural rubber, and its resistance to acids and alkalies is about the same. Elasticity, tear resistance, and rebound are lower than for similarly compounded natural rubber. Hardness may be varied over a wide range. It becomes stiffer than natural rubber at subfreezing temperatures but is reported to be still flexible at -50° C. Resistance to oxidation and decomposition when exposed to heat is said to be excellent, and it is less permeable to air and gases than is natural rubber.

Oil-resistant products made from it include gasoline hose, automobile and aeroplane parts, packing joints and valves, lining for bullet-proof gasoline tanks, printing rollers, and the like. Tires of Ameripol are said to be slightly superior to tires made of natural rubber compounds in abrasive resistance, and are far superior in the presence of oils and high temperatures.

The synthetic is used to produce a hard rubber compound, "Ebonar," which is said to have an outstanding advantage over hard natural rubber as a softening point 100° F. higher is obtainable.

Chemigum

Type: Butadiene copolymer.

Structure: Not announced but said to be a copolymer of butadiene and acrylonitrile similar to Perbunan.

Manufacturer: Goodyear Tire & Rubber Co.

Date announced: 1940.

Present status of manufacture: When announced in 1940, it was stated that Chemigum had been developed and produced in laboratory and pilot plant for 3 years and that a new plant with an initial capacity of 10,000 pounds per day was being erected. No recent figures on its production are available.

Method of production: Not disclosed.

Raw materials and source: Said to be made of butadiene and acrylonitrile. As announced, Chemigum is derived from petroleum through a cracking process.

Method of vulcanization: Like natural rubber.

Method of processing: Said to process more easily than Buna on equipment and by methods used for natural rubber. Tends to be soft and plastic when warm. Mixes well with natural rubber.

Discussion of properties: Specific gravity, 1.06. A Buna-type synthetic rubber. In physical appearance it resembles the grade of rubber known as brown crepe. It has a distinctive, faintly aromatic odor, is tough, and is equal or superior to natural rubber in strength, aging resistance, and resistance to sunlight. It is much less soluble in conventional rubber solvents than natural rubber, and its oil resistance makes it suitable for use in gasoline hose and the like. Tires made of Chemigum are said to give performance equal to or exceeding natural rubber tires.

Neoprene (formerly Duprene)

Type: Polymerized chloroprene.

Structure: $[-CH_2-C\ Cl=CH-CH_2-]_x$.

Manufacturer: E. I. du Pont de Nemours.

Date announced: 1931.

Present status of manufacture: 6,500 long tons produced in 1941. Annua production of 60,000 tons recommended by Baruch committee.

Method of synthesis: Made by polymerization of chloroprene in emulsion under carefully controlled conditions.

Raw materials: Chloroprene.

Method of vulcanizing and processing: Vulcanized by heat alone, but quality of vulcanized products is improved by the use of metallic oxides as vulcanization aids. Processed like natural rubber.

Discussion of properties and uses:

The physical qualities of Neoprene may be modified over a wide range by the proper choice of pigments, accelerators, antioxidants, etc. As with rubber, it is usually necessary to sacrifice some properties to develop others.

Neoprene is made in several types. Neoprene type G is a new, improved, relatively odor-free type made by the polymerization of chloroprene in emulsion under carefully controlled conditions. The unvulcanized neoprene is a plastic with considerable elasticity, like unvulcanized rubber. It is thermoplastic and formed, like rubber, by calendaring, extruding, and molding at high temperatures.

The vulcanized product is resistant to oils, and although virtually all animal, vegetable, or mineral oils cause it to swell somewhat, it usually retains its properties better than rubber. The pure product will not contaminate or alter the properties of solvents or refrigerants with which it comes in contact, however the compounding ingredients in compounded products may, so it is advisable to manufacture the product according to service requirements. It is slightly less elastic than rubber but is more heat-resistant and resists sunlight better. Its loss of properties on freezing is greater than with rubber unless oil-soaked or specially compounded. Type FR was introduced recently and is said to be exceptionally immune to the effect of subzero temperatures.

The specific heat (0.52) of Neoprene is the same as that of rubber. It has approximately the same tensile strength as has similarly compounded rubber. The abrasion resistance of Neoprene tire treads is said to be about equal to that of the best rubber tire-tread compounds. Neoprene and rubber show about equal abrasion resistance when dry, but Neoprene is many times more resistant to abrasion after having been soaked in oil.

Neoprene is used for tank linings, reaction vessels, conveyor belts, gaskets, hose for oils, solvents, and gases such as chlorine, clothing for acid protection, laboratory tubing, and for similar purposes.

Sovprene

Type: Polymerized chloroprene.

Structure: Same as Neoprene.

Manufacturer: Made in U. S. S. R.

Discussion: In a discussion of the chemistry of Sovprene, in an article by Klebanskii and others translated from the Russian in Rubber Chemistry and Technology of July 1936, it is shown that Sovprene is a polymer of chloroprene. This chloroprene is made by adding hydrogen chloride to monovinylacetylene produced from a continuous polymerization of acetylene. It was stated that the successful production of Sovprene was reported in November 1932.

The writer was unable to find articles dealing with the physical properties of Sovprene. In reviews in which it is mentioned it is assumed to be generally like Neoprene.

Mustone

Type: Polymerized chloroprene.

Discussion: Mustone is listed by Wood (see bibliography) as a chloroprene polymer made by Umeno Institute in Japan. He refers to an article by W. J. S. Nauton, Synthetic Rubber, in Annual Report on Progress of Rubber Technology, vol. 1, 1937, p. 35, vol. 2, 1938, p. 31; and vol. 3, 1939, p. 39.

Methyl rubber

Type: Substituted butadiene polymer.

Structure: $[-CH_2-C\ CH_3=C\ CH_3-CH_2-]_x$.

Manufacturers: Bayer & Co., Germany (H and W); Badische Anilin und Soda Fabrik, Germany (B).

Period of manufacture: Made in Germany during first World War, 1914-18; 2,350 tons produced.

Method of synthesis: Polymerization of 2,3 dimethylbutadiene conducted at room temperature to give methyl rubber H or at a higher temperature to give methyl rubber W.

Methyl rubber B was polymerized by means of metallic sodium in an atmosphere of carbon dioxide.

Present status of production: Production was discontinued at the close of the war (1918) because of the cost of the product (30 marks a kilogram).

Raw materials: 2,3 dimethylbutadiene.

Source of raw materials: Dimethylbutadiene was produced from acetone, which was made from calcium carbide.

Method of vulcanizing: Like natural rubber.

Method of processing and compounding: In general, methods of processing were similar to those used at the time with natural rubber, except that it was necessary to add swelling agents or elasticators to increase plasticity. At that time, however, modern methods of compounding natural rubber with carbon black and the like were not known.

Discussion of properties and uses: Methyl rubber H was insoluble in rubber solvents and was used chiefly in the manufacture of hard rubber for accumulator boxes, battery separators, magneto disks, and the like. It had low plasticity and poor adhesive qualities and was not easily milled, although it was used also for insulating wire, and by the spring of 1918 was used in manufacturing tires to some extent. Its use in tires was somewhat unsatisfactory as it was hard and inelastic at ordinary temperatures, and flattened under pressure in cold weather, so that it was necessary to jack trucks equipped with tires made of it. Wear on methyl-rubber tires was found to be different from that on natural-rubber tires, in that pieces of them were ripped or broken off.

Methyl rubber B was more suitable for wire insulation than either H or W, and was more easily milled than H but did not give stronger vulcanized products. W was soluble in rubber solvents and was used successfully in high-pressure packing, in other rubber-asbestos goods, in balloon fabric, and as insulation for submarine cables and ordinary wire.

As mentioned above, failure of methyl rubber as a substitute for natural rubber is attributed to lack of an understanding of compounding as much as to the character of the rubber itself.

Vistanex

Type: Polymerized isobutylene.

Structure: $[-CH_2-C(CH_3)_2-]_x$.

Manufacturer: Standard Oil Co. of N. J.; Advance Solvents & Chemical Corporation.

Date announced: 1937.

Present status of manufacture: Data not available.

Method of synthesis: Isobutylene polymerized at low temperatures with catalysts of an acidic nature, such as titanium tetrachloride, boron fluoride, and aluminum chloride.

Raw materials and source: Isobutylene from cracking of petroleum.

Method of vulcanizing: Cannot be vulcanized.

Discussion of properties and uses: Vistanex (and Oppanol) possesses unique qualities owing to its lack of unsaturation. It exhibits extreme resistance to ozone, acids, alkalies, and corrosive salts and has excellent aging properties, especially at high temperatures. Its water-absorption and vapor-permeability properties are extremely low. It is resistant to most vegetable and animal fats, oils, and greases, and is insoluble in alcohols, esters, ketones, and most organic solvents containing oxygen; but it is soluble in petroleum and coal-tar solvents and in some chlorinated solvents. It has excellent electrical properties. It is less thermoplastic, and the degradation or breakdown by mechanical milling or mixing is less than for natural rubber.

Vistanex is used in the manufacture of cable sheathing, acid-resistant linings, electrical insulation, adhesives, artificial leather, and the like. It may be compounded with natural rubber in certain proportions to give a curable product useful in steam hose, conveyor-belt covers, cable coverings, and other products resistant to aging or chemical action.

Isobutylene polymers are made in a wide range of molecular weights for use in oils and greases for increasing viscosity.

Oppanol

Type: Polymerized isobutylene.

Structure: Same as Vistanex.

Manufacturer: I. G. Farbenindustrie, Germany.

Date announced: 1937.

Discussion: Oppanol was developed by I. G. Farbenindustrie in cooperati with Standard Oil Co. of N. J. and is the same as Vistanex, which is made in the United States. For properties, uses, and discussion, see Vistanex.

Butyl Rubber

Type: Copolymer of a butene and a diolefin.

Structure: $\left[[-CH_2-C(CH_3)_2-]_x-CH_2-CH=CH-CH_2- \right]_y$.

Manufacturer: Standard Oil Co. of New Jersey.

Date announced: 1940.

Method of synthesis: Produced by low-temperature copolymerization of isobutylene and a small amount of butadiene or other diolefin.

Present status of production: Annual production of 132,000 tons is planned under the present program of the War Production Board.

Digitized by Google Original from THE OHIO STATE UNIVERSITY

Raw materials: Isobutylene and butadiene or isoprene.

Source of raw materials: Isobutylene procured from petroleum by cracking. See also Butadiene. Isoprene from petroleum or turpentine.

Method of vulcanizing: Like natural rubber. Chemical unsaturation just sufficient for vulcanization.

Method of processing and compounding: May be processed like natural rubber on conventional rubber machinery. No breakdown period is necessary. Its curing temperature is above 300° F.

Discussion of properties and uses: Butyl rubber is outstanding in that it possesses only 1 or 2 percent of the available unsaturation of natural rubber, which is just enough for vulcanization. This lack of unsaturation gives butyl rubber unusual properties in aging resistance and in stability in the presence of ozone. It swells like natural rubber in petroleum and coal-tar solvents but does not swell in most vegetable and animal fats and oils. It is resistant to acids, including sulfuric and nitric, has low water absorption, high heat resistance, and excellent flex resistance, and is highly impermeable to air and gases such as hydrogen, helium, and carbon dioxide. Its rebound is low at room temperature but high at high temperatures. The general range of molecular weight is between 40,000 and 80,000, and the specific gravity is 0.91. It is colorless, odorless, and tasteless. Electric properties are said to be such as to make it outstanding for cable insulation.

Butyl rubber is said to be satisfactory for inner tubes, as it holds air longer than does natural rubber and is considered superior to certain other synthetic rubbers for this purpose, although some difficulties have been experienced. So far, automobile tires made of butyl rubber have shown a life about 50 percent as long as that of natural-rubber tires if used at a speed under 40 miles an hour. Besides its use in tires and tubes, it is recommended for use in fire and steam hose, molded goods, proofed goods, tank linings, conveyor belts, and in general replacement of natural rubber.

Flexon

Type: Copolymer of a butene and a diolefin.

Structure: Similar to butyl rubber.

Manufacturer: Standard Oil Co. of New Jersey.

Date announced: 1942.

Method of synthesis: Produced by copolymerization of isobutylene and butadiene or other diolefin using dry ice in an open vessel.

Present status of production: Still in the experimental stage.

Raw materials and source: Same as butyl rubber.

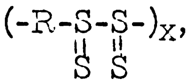
Method of vulcanizing and processing: Same as butyl rubber.

Discussion of properties: Flexon is an inferior grade of butyl rubber produced at the temperature of dry ice. In producing butyl rubber, a temperature of -153° F. is used, whereas Flexon is made at a temperature of -103° F. Results are said to be not too satisfactory as yet, owing to a lack of uniformity in the product, but it is offered as a rubber producible by a quick method, which may be suitable for retreads.

Thiokol

Type: Organic polysulfide.

Structure:



$(-R-\underset{\underset{S}{\|}}{S}-\underset{\underset{S}{\|}}{S}-)_x$, where R is an organic radical such as $(-CH_2-CH_2-)$ or $(-CH_2-CH_2-O-CH_2-CH_2)$, depending on aliphatic dihalide used.

Manufacturer: Thiokol Corporation, Yardville, N. J. (Dow Chemical Co.)

Date announced: 1932.

Date first available references: 1932.

Patent: U. S. 1854423, April 19, 1932, Patrick.

Present status of manufacture: Made in several grades and types. Annual production of 24,000 tons under present program; 60,000 tons recommended by Baruch committee.

Method of synthesis: Reaction between organic dihalide and alkali polysulfide.

Raw materials: Dependent on type. Ethylene dichloride and sodium tetrasulfide give Thiokol A; dichloroethyl ether and sodium tetrasulfide give Thiokol B; etc.

Source of raw material: The organic compounds, which may be obtained from petroleum products, are chlorinated by chlorine obtained from salt. The sulfides are made from sulfur and alkali.

Method of processing and vulcanizing: Processed on regular rubber machinery by special methods. Lacks tack and adaptability. Is frequently mixed with natural rubber. Reinforcing pigments and modifying agents are added, as with natural rubber. Vulcanizes with metallic oxides, sulfur being used as an accelerator.

Discussion of properties, types, and uses: Thiokol has been made in several types and from several primary materials. A variety of products, some of which are rubberlike and some of which are not, can be made by varying the kind of polysulfide and hydrocarbon. Some of the products are used in the plastic industry and some as a rubber substitute. The rubberlike types are soft and plastic and can be worked on a rubber mill and reinforced and modified by the addition of compounding agents just as with natural rubber. They are particularly resistant to organic solvents. The ethylene polysulfides are virtually inert to all organic solvents, including benzol, toluol, xylol, carbon tetrachloride, lacquers and lacquer thinners, acetone, water, salt solutions, dilute phenol, sulfuric acid, hydrochloric acid, and acetic acid, whereas other types are resistant to petroleum but swell to varying degrees in certain chlorinated and aromatic hydrocarbons. They are not recommended for use with strong nitric or chromic acid nor for caustic soda or ammonia. They show excellent resistance to ozone, oxygen, and sunlight, but are low in tensile strength, heat resistance, and abrasion resistance. They burn slowly and have relatively poor electrical properties, but good enough for low-voltage insulation. They are not recommended for use at extreme temperatures, as they harden at subzero temperatures and are subject to plastic flow at temperatures slightly above atmospheric. They are nontoxic but possess a disagreeable odor. They are highly impermeable and are apparently the most resistant of any of the synthetic rubbers to gasoline, benzene, and oil.

Thiokol A, the first to be manufactured, is a reaction product of ethylene dichloride and sodium tetrasulfide. It is insoluble in all organic solvents and does not swell to any extent even in the most active solvents, but is attacked by strong oxidizing agents and alkalies. It is highly impermeable to liquids and gases. In general, the rubberlike properties do not equal natural rubber. Thiokol A is unaffected by ozone, sunlight, weathering, or natural aging, but hardens at low temperatures and is not recommended above 160° F. Its greatest use in the cable industry is as a noninsulating flexible jacket that offers protection nearly equal to lead. It is also used on cables in contact with oil or solvents, on underground cables exposed to moisture and corrosion, and to replace lead where vibration is severe, as on bridges. It is also used in the preparation of sulfur-sand acid-resisting cement and for certain special jobs, such as mouldings, where extreme resistance to solvents is necessary.

Type D, made from a different hydrocarbon, is similar to A but has higher physical properties and abrasion resistance, lower moisture resistance, less odor, and can be used over a wider range of temperatures (-40° to 212° F.).

The latter type, F (and FA), is more rubberlike than its predecessors and combines the qualities of both A and D, is resistant to petroleum and other solvents, has a tensile strength up to 1,500 pounds per square inch, high resilience, and abrasion resistance two thirds that of natural rubber.

Thiokol is not suitable for tire treads, although a new type (N) is said to be suitable for recapping tires. In general, Thiokol may be used where high resilience, tensile strength, and resistance to heat are not important, but where good aging characteristics, resistance to ozone and solvents, and flexibility are required. It is used in the automotive industry for coating paper gaskets, where it flows under heat and pressure into tool marks and imperfections to make a perfect oil seal. It is used, also, in the manufacture of gasoline and paint-spray hose, printers' blankets, rubber printing plates, and cable coverings.

Thiokol R D

Type: Not announced. Not a polysulfide rubber.

Structure: Not given.

Manufacturer: Thiokol Corporation, Trenton, N. J.

Date announced: 1942.

Date first available article: 1942.

Present status of manufacture: Not stated.

Raw materials: Not listed.

Method of vulcanizing: Much like natural rubber. Sulfur acts as a vulcanizing agent. Does not cure to the hard-rubber state with sulfur.

Processing: Much like natural rubber. Plasticized through use of a plasticizer. Shows wide variation of properties according to method of compounding.

Discussion of properties: In the only article available on Thiokol R D, the following properties are listed:

> In the raw state it is a tough, resilient, amber-colored, solid.
> Sp. gr., 1.03.
> Odor mild and not objectionable.
> Excellent resistance to gasoline, oil, and other solvents. Does not have all solvent-resistant properties of Thiokol FA.
> High tensile strength, up to 3,000 pounds per square inch.
> Good abrasion resistance, comparable to natural rubber.
> Low compression set.
> Elongation at break, 400 percent.
> Good resistance to flex cracking.
> Low permeability to air and gases.
> Good aging characteristics.

Ethanite

Type: Organic polysulfide.

Structure: See Thiokol.

Date of first reference: 1934.

Manufacturer: Belgian Cracking Co., Belgium.

Method of synthesis: Polymerization of ethylene dichloride in the presence of a sodium polysulfide solution.

Source of raw materials: Olefins in cracked gas are chlorinated to produce ethylene dichloride.

Discussion of properties: Apparently like Thiokol.

Perduren

Type: Organic polysulfide.

Structure: See Thiokol.

Date of first available reference: 1937.

Manufacturer: I. G. Farbenindustrie, Germany.

Method of synthesis: Reaction product of dichloroethyl ether or di (chloroethyl) formaldehyde acetal with sodium tetrasulfide.

Source of raw material: No reference.

Methods of processing: Like Thiokol. Sometimes mixed with Perbunan.

Discussion of properties: From scant available references it appears that the types of Perduren have properties in common with the American-made Thiokols.

Thionite and Thionoc

Type: Organic polysulfide.

Discussion: The only available reference to Thionite was the paper by Wood (see bibliography), which listed an article not available to the writer. Wood states that Thionite is a Japanese product obtained from the reaction of ethylene diglycoside with sodium tetrasulfide. Thionoc A is referred to in the abstract of a Japanese article as a polysulfide rubber, presumably made in Japan.

Vulcaplas

Type: Organic polysulfide.

Structure: See Thiokol.

Date of first available reference: 1940 (refers to British patent 453,850, issued Sept. 18, 1936.)

Manufacturer: Imperial Chemical Industries, England. No references available as to status of manufacture.

Method of synthesis: Reaction product of glycerol dichloro- (or dibromo-) hydrin with ammonium or alkali di- or polysulfide.

Source of raw materials: No reference.

Methods of processing and vulcanizing: Like Thiokol.

Discussion of properties: Very few references were found dealing with Vulcaplas by name. However, such references as are available indicate that the properties of Vulcaplas are common with Thiokols and include complete immunity to swelling in rubber solvents, lower tensile strength and less rubberlike character than other synthetic rubbers, strong objectionable odor, and cold flow or thermoplasticity.

Koroseal and Korogel

Type: Plasticized polymerized vinyl chloride.

Structure: $[-CH\,Cl-CH_2-]_x$.

Manufacturer: B. F. Goodrich Co.

Date announced: 1935.

Raw materials: Vinyl chloride and plasticizer.

Method of vulcanizing: Not vulcanizable.

Method of processing: Plasticized with any of a number of plasticizers according to qualities desired. Processed on standard rubber processing equipment. May be milled, molded, extruded, calendered, or coated on fabric or paper, and solutions may be applied by spreading, dipping, or printing.

Discussion of properties and uses: The term "Koroseal" is said to refer to a broad class of compositions having properties varying from those of hard rubber to those of a jellied cement. Korogel is highly plasticized Koroseal, and Korolac is a solution of Koroseal in specially selected solvents.

> The physical and chemical properties of Koroseal may be varied over a wide range by the choice of plasticizer. With proper plasticizer it can be made transparent. The tensile strength is varied from 1,000 to 9,000 pounds per square inch; elongation may be varied from 2 to 500 percent; flexing life, if used alone, is ten times that of natural rubber; tearing strength is equal to or slightly exceeds that of the best rubber compounds; and at atmospheric temperature resistance to abrasion is better than that of rubber. However, Koroseal is unsuitable for the manufacture of automobile tires,

as it undergoes plastic flow at high temperatures. Its impact strength and volume compressibility are similar to those of natural rubber, and compression set is in general greater than that of rubber.

The harder types of Koroseal are resistant to virtually all materials except organic compounds containing the nitro or chlorine groups, aliphatic or aromatic ketones, aromatic amino compounds, lacquer solvents, or acetic anhydride. In addition, the plasticizer of the softer grades may be partly extracted by certain oils, gasoline, or benzene. Koroseal is resistant to corrosive chemicals, acids, alkalies, and water; it is not affected by sunlight, aging, oxygen, or ozone, and is very superior to rubber in resistance to gas diffusion. It can be made odorless, is tasteless, and nontoxic with proper choice of plasticizer.

Koroseal is used in the manufacture of process equipment for chemical and allied industries, in pipe-line coating materials, balloon cloth, chemical tubing, vacuum and gas materials, electrical insulation, protective paints, belting, gaskets and packing, clothing and waterproof cloth such as wraps and shower curtains, upholstery, and for special uses in the cable and textile industries.

Korogel, a highly plasticized form of Koroseal, is especially useful as a matrix material for plaster of Paris, portland cement, and ceramics molding.

Flamenol

Type: Plasticized polymerized vinyl chloride.

Structure: $[-CH\ Cl-CH_2-]_x$.

Manufacturer: General Electric Co.

Date of first reference: 1937.

Discussion: Flamenol is described as a synthetic compound resembling rubber, which serves both as an insulation and a finish for wire and cable. Its properties are said to include high dielectric strength, toughness, strength, stability in sunlight and oxygen, stability to ozone and oxidizing chemicals and to oils, solvents, acids, and alkalies, and resistance to flame and moisture

Agripol

Type: A chemurgic product made from soybean oil. Insufficient information available for classification.

Manufacturer: Reichhold Chemicals, Inc., Detroit, Mich.

Date announced: November 30, 1942.

Present status of manufacture: 125 tons a month, to be increased to 1,000 tons a month by February 1943. Contemplated annual production of 25,000 tons in 1943.

Method of synthesis: Polymerization of fatty acids and ethylene glycol.

Raw materials and source: Fatty acids extracted from soybean oil. Ethylene glycol made by dehydration of ethyl alcohol.

Method of vulcanizing: About the same as for natural rubber.

Method of processing: Can be worked and formed in existing rubber equipment and compounded with customary fillers used with natural rubber.

Discussion: Agripol was announced late in 1942 as being a product inferior to natural rubber in tensile strength and resistance to severe abrasion. Hence, it is not claimed to be suitable for tires but is expected to prove useful in the field of static rubber, where tensile strength and elongation are not essential. It is said to be equivalent to natural rubber in flexibility at low temperatures and superior to natural rubber in aging and resistance to oxidation. Suggested uses for Agripol are in gaskets for food containers, industrial gaskets, belting, insulating mats, hose linings, and the like, as well as in numerous gadgets and parts for military supplies and equipment.

BIBLIOGRAPHY

ANDERSON, J. G. Processing and Applications of Synthetic Rubber. Trans. Inst. Rubber Ind., vol. 14, No. 5, February 1939, p. 266; Chem. Abs., vol. 33, 1939, p. 5701.

AUTOMOTIVE INDUSTRIES. G. E. Publishes Data on Flamenol. Vol. 83, August 15, 1940, p. 187.

BARUCH COMMITTEE. Report on Rubber Problem. Nat. Petrol. News, vol. 34, No. 37, September 16, 1942, p. 21; Petrol. Refiner, vol. 21, No. 10, October 1942, p. 294; Ind. Eng. Chem., vol. 34, No. 11, November 6, 1942, p. 1256.

Chemistry of Synthetic Rubber - Supplement to Baruch Committee Report: Petrol. Refiner, Vol. 21, No. 11, November 1942, p. 144.

BLANK, H. E., Jr. Synthetic Rubberlike Materials in the Automotive Field. Automotive Ind., vol. 80, June 15, 1939, p. 700; Chem. Abs., vol 33, 1939, p. 6649.

BRIDGWATER, E. R. Neoprene as a Construction Material for the Chemical Industry. Trans. Am. Inst. Chem. Eng., vol. 35, August 1939, p. 435.; Chem. Abs., vol. 33, 1939, p. 7622.

Physical Properties of DuPrene Compounds. Ind. Eng. Chem., vol. 26, No. 1, January 1934, p. 33.

BROUS, S. L. and SEMON, W. L. Koroseal, A New Plastic: Ind. Eng. Chem., vol. 27, No. 6, June 1935, p. 667; India Rubber World, vol. 92, September 1935, p. 45, vol. 93, October 1935, p. 43.

CAROTHERS W. H., WILLIAMS, IRA, COLLINS, A. M. and KIRBY, J. E. Acetylene Polymers and Their Derivatives. II. A New Synthetic Rubber, Chloroprene and Its Polymers. Jour. Am. Chem. Soc., vol. 53, November 1931, p. 4203; Chem. Abs., vol. 26, 1932, p. 78.

Rubber from Soybeans. Chemurgic Digest, vol. 1, No. 22, November 30, 1942, p. 169; Chem. and Eng. News, vol. 21 No. 2, January 25, 1943, p. 108.

CLARKE, R. B. Processing of Neoprene. Trans. Inst. Rubber Ind., vol. 16, No. 2, August 1940, p. 51; Chem. Abs., vol. 35, 1941, p. 4994.

CRAMER, HOWARD I. Industrial Progress in Synthetic Rubberlike Polymers. Ind. Eng. Chem., vol. 34, No. 2, February 1942, p. 243.

CRANE, T. G. Thiokol. Trans. Inst. Rubber Ind., vol. 17, No. 3, October 1941, p. 139.

CROSBY, J. D. "Thiokol" Synthetic Rubber, Type R D. India Rubber World, vol. 106, No. 2, May 1942, p. 133.

DINSMORE, R. P. Chemigum - A New Elastomer. Ind. Eng. Chem., News Ed. vol. 18, No. 17, September 10, 1940, p. 757; Chem. Abs., vol. 35, 1941, p. 61.48.

EGLOFF, GUSTAV. Synthetic Rubber from Petroleum. Rubber Age, vol. 52, No. 3, December 1942, p. 221.

BIBLIOGRAPHY (Cont'd.)

FISHER, HARRY L. Nomenclature of Synthetic Rubbers. Ind. Eng. Chem., vol. 31, No. 8, August 1939, p. 941; Rubber Chem. and Tech., vol. 12, 1939, p. 900; India-Rubber World, vol. 100, No. 6, September 1939, p. 27; India Rubber Jour. vol. 99, 1939, p. 85; Chem. Abs., vol. 33, 1939, p. 8443.

Natural and Synthetic Rubbers (Edgar Marburg Lecture). Proc. Am. Soc. Testing Materials, vol. 41, 1941, (31 pp.), p. 521; Chem. Abs., vol. 36, 1942, p. 679.

GARTNER, E. Buna for Hard-Rubber Linings. Rubber Chem. and Tech., vol. 14, 1941, p. 899; Trans. from Kautschuk, vol. 16, No. 9, September 1940, pp. 109-116; Chem. Abs., vol. 35, 1941, p. 4994.

GARVEY, B. S., Jr., JUVE, A. E., and SAUSER, D. E. Hycar OR, Properties of Typical Compounds. Ind. Eng. Chem., vol. 33, No. 5, May 1941, p. 602; Chem. Abs., vol. 35, 1941, p. 5348.

GROSSE, ARISTID V., MORRELL, JACQUE C., and MAVITY JULIAN M. Catalytic Dehydrogenation of Monoolefins to Diolefins: Source Materials for Synthetic Rubber and Resins. Ind. Eng. Chem., vol. 32, No. 3, March 1940, p. 309; reprinted in Rubber Chem. & Tech., vol. 13, No. 3, July 1940, p. 533; Chem. Abs., vol. 34, 1940, p. 2646.

INDIA RUBBER WORLD. Ethanite. Vol. 89, No. 6, 1934, p. 40.

Ameripol, New Butadiene Synthetic Rubber. Vol. 102, July 1940, p. 47.

Goodyear Announces Chemigum, Its New Synthetic. Vol. 102, September 1940, p. 59; Oil and Gas Jour., vol. 39, September 5, 1940, p. 44; Rubber Age, vol. 47, September 1940, p. 399.

Ind. Eng. Chem., News Ed.; Russian Synthetic Rubber. vol. 14, November 20, 1936, p. 451.

Ind. Eng. Chem., News Ed., Rubber from Alcohol; Synthetic Process in Russia, vol. 14, June 20, 1936, p. 243; Chem. Ind., vol. 39, July 1936, p. 49; Rubber Age, vol. 39, July 1936, p. 216.

JONES, MALDWYN. Synthetic Rubber. Annual Report on the Progress of Rubber Technology, vol. 4, 1940, p. 40.

KLEBANSKII, A. L., TZYURIKH, L. G. and DOLGOPOL'SKII, I. M. [Chloroprene Synthetic Rubber (Sovprene)]. Bull. Acad. Sci. (USSR), No. 2, June 1935, p. 189; trans. in Rubber Chem. and Tech., vol. 9, July 1936, p. 384; Jour. Res. Assoc. Brit. Rubber Mfg., vol. 4, 1935, p. 505; Chem. Abs., vol. 30, 1936, p. 1259.

KOCH, ALBERT. Specific Properties of Artificial (Buna) Rubber. Rubber Chem. and Tech., vol. 10, No. 1, January 1937, p. 17; trans. from Ztschr. Ver. deut. Ing., vol. 80, No. 32, August 18, 1936, p. 963; Chem. Abs., vol. 30, 1936, p. 8680, vol. 31, 1937, p. 2359.

Buna Rubber. Ind. Eng. Chem., vol. 32, No. 4, April 1940, p. 464; Chem. Abs., vol. 34, 1940, p. 3129.

BIBLIOGRAPHY (Cont'd.)

KLEBSATTEL, C. A. Perbunan and Its Uses. India Rubber World, vol. 102, August 1940, p. 33, September 1940, p. 37, vol. 103, October 1940, p. 45; Chem. Abs., vol. 35, 1941, p. 2366.

LIGHTBOWN, I. E. The Compounding and Processing of Butyl Rubber. Rubber Age, vol. 51, No. 5, August 1942, pp. 377-380.

Some Properties of Perbunan. Rubber Age, vol. 47, April 1940; p. 19; Chem. Abs., vol. 34, 1940, p. 3484.

LONGMAN, S. Vistanex Polybutene- Rubber Blends. Rubber Chem. and Tech., vol. 14, 1941, p. 386; Chem. Abs., vol. 35, 1941, p. 8363.

McCORTNEY, W. J. Economics of Substituting Synthetic Rubber in Automobiles Jour. Soc. Automotive Eng., vol. 48, No. 3, March 1941, p. 94.

MARCHIONNA, FREDERICK. Abstracts of United States Patents on the Compounding and Use of Synthetic Rubber. Rubber Age, vol. 51, No. 3, June 1942, p. 209 and cont'd.

MARTIN, S. M. Thiokol Synthetic Rubber - Type F A. India Rubber World, vol. 104, No. 6, 1941, p. 30; Chem. Abs., vol. 35, 1941, p. 8363.

MARTIN, S. M., Jr., and PATRICK, J. C. Constitution of Polysulfide Rubbers. Ind. Eng. Chem., vol. 28, No. 10, October 1936, p. 1144.

NPN NEWS BUREAU. Jersey Standard Shows Congressmen How to Make Rubber in a Test Tube. Nat. Petrol. News, vol. 34, No. 29, July 22, 1942, p. 22.

NPN NEWS BUREAU. Synthetic Rubber Plants Listed. Nat. Petrol. News, vol. 34, No. 29, July 22, 1942, p. 20.

PATRICK, J. C. The Formation of High Polymers by Condensation between Metallic Polysulfides and Dihalogenated Hydrocarbons and Ethers. Rubber Chem. and Tech., vol. 9, No. 3, July 1936, P. 373; reprinted from Trans. Faraday Soc., vol. 32, No. 177, part 1, January 1936, pp. 347-35 Chem. Abs., vol. 30, 1936, p. 2462.

PENNESCU, RAZVAN C. B. [Manufacture of Synthetic Resins. Ann. Soc. Belge Étude Petrole,] vol. 1, No. 2, 1937, p. 21; Chem. Abs., vol. 33, 193 p. 7429.

ROELIG, H. Buna in the Manufacture of Cables. Rubber Chem. and Tech., vol. 13, No. 4, October 1940, p. 949; trans. from Kautschuk, vol. 16, No. 3, March 1940, pp. 26-33; Chem. Abs., vol. 35, 1941, p. 4634.

ROSSMAN, JOSEPH. Synthetic Rubber (Patent Abstracts). India Rubber World, vol. 94, 1936, May p. 31, June p. 28, July p. 43, August p. 30, September p. 40, vol. 95, October p. 45, November p. 45, December p. 48, January 1937 p. 54; Chem. Abs., vol. 30, 1936, pp. 7384, 8679.

RUBBER AGE. Vistanex - Polymerized Hydrocarbon. Vol. 41, No. 2, May 1937, p. 102; Chem. and Met. Eng., vol. 44, 1937, p. 686, Chem. Ind., vol. 40, 1937, p. 609.

Thiokol Type F. Vol. 47, July 1940, p. 246.

Properties, Processing and Compounding of Hycar OR Synthetic Rubber. Rubber Age, vol. 48, February 1941, p. 315.

Goodyear's Chemigum. Vol. 48, No. 6, 1941, p. 399.

BIBLIOGRAPHY (Cont'd.)

CHADE, J. W. Rubbers, Natural and Synthetic. Jour. Aeronaut. Soc. vol. 8, p. 177, Mfrs. Record, vol. 110, Nos. 3 and 4, pp. 26 and 24; Rubber Age (NY), vol. 48, No. 6, March 1941, p. 387; Chem. Abs., vol. 35, 1941, pp. 3845, 4627.

CHATZEL, R. A., and CASSELL, G. W. Synthetic Elastic Polymers in the Cable Industry. Ind. Eng. Chem., vol. 31, No. 8, August 1939, p. 945.

CHOENFELD, F. K. Koroseal as an Engineering Material. Trans. Am. Inst. Chem. Eng., vol. 35, 1939, p. 447.

CHOENFELD, F. K., BROWNE, A. W., Jr., and BROUS, S. L. Recent Developments with Koroseal. Ind. Eng. Chem., vol. 31, No. 8, Aug. 1939, p 964.

EBRELL, L. B. and DINSMORE, R. P. Properties of Some Synthetic Rubbers India Rubber World, vol. 103, March 1, 1941, p. 37; vol. 104, No. 1, 1941, p. 45; Jour. Soc. Automotive Eng. (Trans.), vol. 49, No. 3, September 1941, p. 368; Automobile Eng., vol. 31, 1941, p. 135; Chem. Abs., vol. 35, 1941, pp. 5746-8362.

PARKS, W. J., LIGHTBOWN, I. E., TURNER, L. B., FROLICH, P. K. and KLEBSATTELL, C. A. Rubberlike Properties of Polybutene. Ind. Eng. Chem., vol. 32, No. 5, May 1940, p. 731; reprinted in Rubber Chem. and Tech., vol. 13, 1940, p. 521.

TARKWEATHER, HOWARD W., and YOUKER, MORTIMER A. Plasticization of Neoprene, Type G. Ind. Eng. Chem., vol. 31, No. 8, August 1939, p. 934, Chem. Abs., vol. 33, 1939, p. 8444.

TREET, J. N., and DILLON, J. H. Physical Characteristics of Synthetic Rubbers. Jour. Appl. Physics, vol. 12, January 1941, p. 45; Chem. Abs., vol. 35, p. 2030.

TREET, J. N., and EBERT, H. L. The Use of Synthetic Rubber in the Automotive Industry from the Viewpoint of the Rubber Technologist. Rubber Chem. and Tech., vol. 14, 1941, p. 211; Chem. Abs., vol. 35, 1941, p. 4633.

TOCKLIN, P. Buna. Trans., Inst. Rubber Ind., vol. 15, No. 1, June 1939 p. 51.

ALALAY, ANSELM, and TALALAY, LEON. SK- the Russian Synthetic Rubber from Alcohol. Rubber Chem. and Tech., vol. 15, No. 3, July 1942, p. 403.

HOMAS, R. M., LIGHTBOWN, I. E.,SPARKS, W. J., FROLICH, P. K., and MURPHREE, E. V. Butyl Rubber, A New Hydrocarbon Product. Ind. Eng. Chem., vol. 32, No. 10, October 1940, p. 1283; reprinted in Rubber Chem. and Tech., vol. 14, 1941; abs., Chem. Ind., vol. 47, October 1940, p. 375; reprinted in Kautschuk, vol. 17, 1941, p. 36; Chem. Abs., vol. 34, 1940, p. 8334, vol. 36, 1942, p. 2445.

THOMAS, R. M., SPARKS, W. J., FROLICH, P. K., OTTO, M., and MUELLER-CUNRADI, M. Preparation and Structure of High Molecular Weight Polybutenes. Jour. Am. Chem. Soc., vol. 62, 1940, p. 276.

BIBLIOGRAPHY (Cont'd.)

TUTTLE, JOHN B. Petroleum in Rubber. A Complete Review of the Present Uses of Petroleum Products in the Compounding of Rubber and Some Possible Future Uses. Rubber Age, vol. 49, 1941, p. 23.

VOGE, LAW. German Patents Relating to Synthetic Rubberlike Materials. India Rubber World, vol. 102, 1940, April 1 p. 48; May 1 p. 47; July 1 p. 45, August 1 p. 43, September 1 p. 41; vol. 103, October 1 p. 41, November 1 p. 39, December 1 p. 53; July 1941, p. 49.

German Patents Relating to Vinyl Polymers. India Rubber World, vol. 105, No. 1, 1941, p. 37; Chem. Abs., vol. 35, p. 8363.

WHITBY, G. S., and KATZ, M. Synthetic Rubber. Ind. Eng. Chem., vol. 25, No. 11, November 1933, p. 1204; December 1933, p. 1338.

WOOD, LAWRENCE A. Synthetic Rubbers: A Review of Their Composition, Properties, and Uses. Nat. Bureau of Standards, Circ. 427, June 25, 1940, 29 pp., incl. bibliog. of 228 references; Rubber Chem. and Tech., vol. 13, 1940, pp. 861-885.

YERZLEY, FELIX L., and FRASER, DONALD F. Effects of Low Temperatures on Neoprene Vulcanizates. Ind. Eng. Chem., vol. 34, No. 3, March 1942, p. 332.

YERZLEY, FELIX L. Adhesion of Neoprene to Metal. Ind. Eng. Chem., vol. 31 No. 8, August 1939, p. 950; reprinted in Rubber Chem. and Tech., vol. 13, No. 1, January 1940, p. 166; Chem. Abs., vol. 33, 1939, p. 9044.

ZEDER, J. C., Synthetic Rubber in the Automotive Industry. India Rubber World, vol. 103, No. 6, March 1, 1941, p. 48.

- - - - - -

Technical Journal issues devoted to synthetic rubber:

Industrial and Engineering Chemistry, vol. 34, No. 11, November 1942. Twenty-five papers which were presented before the General Meeting and the Division of Rubber Chemistry at the 104th Meeting of the American Chemical Society, Buffalo, N. Y. are printed in this issue.

Oil and Gas Journal, vol. 41, No. 29, Nov. 26, 1942. Rubber from Petroleum Issue. Twenty-two articles.

Petroleum Refiner, vol. 21, No. 10, October 1942. War Products Issue. Sixteen articles.